Power Density & Efficiency Optimization of existing Low Density Datacenters

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Challenges...............

Continuously increasing Energy consumption for growing computing needs!!!!!!!!!!!

Energy use of computing devices is an increasing concern

- **Total U.S use is about 100B kwhrs. in 2006***
- **Projected to grow 3-4% per year***
- **Energy costs likely to continue increasing**
  - **Supply issues; potential climate change regulations**

The same is reflected in the Datacenter energy consumption also..

U.S. data center electricity use ~30B kwhrs/yr. *

Energy is top data center operating cost

Public perception that data centers are driving up energy use

Worldwide server shipments 7M/ year and growing 10% per year *

*** Source – Energy Efficient computing – Tim Higgins, Intel Dt: 5/8/07**

Challenges to Energy Efficiency in Data centers

Right Sizing of facility infrastructure considering appropriate load diversity.

Efficiency of the UPS systems

Power used for cooling in the data center

Power and Cooling Distribution Architecture inside the data center

Redundant Infrastructure requirements for higher reliability needs impacting efficiency

Older generation servers yielding less performance per watt of power consumed as compared to the current generation multi core servers.

Geographical location/ Site selection related constraints like Humidity issues, Environment temperature issues, Utility reliability etc.

Scope of this discussion

Key Metrics – PUE (Power Usage Efficiency) , Metering & Monitoring & resulting benefits

Case Study – Measuring Efficiency in DC (Data Center) “A”@110W/Sq feet. Vs DC (Data Center) ”B” @250W/Sq feet.

Actionable – Up gradation of existing Low density Datacenter to High Density with minimal retrofits.

Key Takeaway - Resulting Improvement in efficiency of the Datacenter providing the ROI for the retrofit within the short time period.

Key Metrics – PUE (Power Usage Effectiveness)- source Green Grid*

The Power Usage Effectiveness (PUE) is defined as follows:

PUE = **Total Facility Power / Total IT Equipment Power**

and its reciprocal the Data Center Efficiency (DCE) is defined as,

DCE = 1/ PUE

= **Total IT Equipment Power / Total Facility Power**

*** Green Grid is a global consortium dedicated to advancing energy efficiency in Datacenters and Business computing eco systems. PUE is an DC Efficiency metric propounded by Green Grid.**

Key Metrics – Total Facility Power

The Total Facility Power is defined as the power measured at the utility meter, and is that power dedicated solely to the data center (this is important in mixed use buildings that house data centers as one of a number of functions).

This essentially includes everything that supports the IT Equipment Load such as:

- Power delivery components such as UPSs, switch gear, generators, PDUs, batteries and distribution losses external to the IT equipment.
- Cooling System components such as chillers, Computer Room Air Conditioning Units (CRACs), Direct Expansion Air handler (DX) units, pumps, cooling towers and automation
- Compute, Network and Storage nodes
- Other miscellaneous component loads such as data center lighting, fire protection system etc.

Key Metrics - Total IT Equipment Power

The IT Equipment Power is defined as the effective power used by the equipment that is used to manage, process, store, or route data within the raised floor space

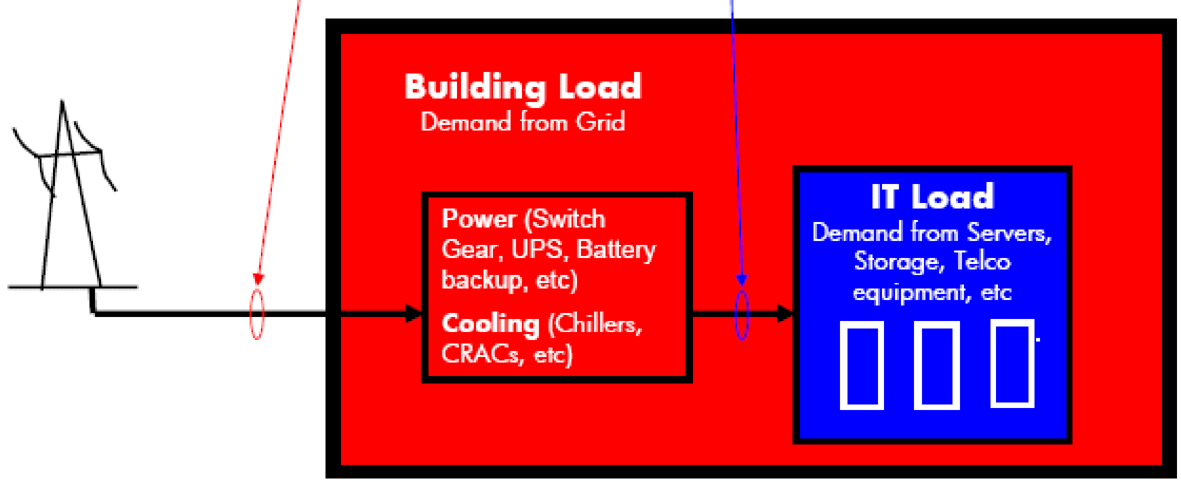
This includes the load associated with all of the IT Equipment and includes compute, storage and network equipment, along with supplemental equipment such as KVM switches, monitors, and workstations/laptops used to monitor or otherwise control the data center.

Typically it is monitored at the Rack level using metered PDUs however the more effective approach is to continuously monitor at the ROW Level in the Electrical Distribution box with Energy Meters.

Key Metrics - Power metering points

PUE – Power Usage Effectiveness
DCE – Data Center Efficiency

PUE = **Total Facility Power** / **IT Equipment Power**



DCE = 1/PUE = **IT Equipment Power** / **Total Facility Power**

Need for Power/Cooling efficiency monitoring

"You can't manage what you can't measure"- Andy Grove.

The primary focus is

- To measure the existing energy efficiency levels
- Identify current operational power costs & Set the base line
- Target the potential cost saving opportunities & Set the goal line
- Implement the Efficiency Improvement process, based on the existing knowledge base and drive towards the goal line
- Continuously measure and keep working on improvements in the DC operational cost structures.

Efficiency Improvement process

Air Side –

- Right Sizing, Delivery, Supply Air- return Air isolation (Containment), AC Coil Delta, PAC temp and Humidity set points, Diffuser selection, Use of Blanking panels, Brush Grommets, Wet side economizer, Optimizing supply plenum Static pressure, Use of Air flow calculator and Tile flow analysis to optimally balance the Load across the Data Center floor Area, Containerized DC approach

Power Side –

- UPS Sizing, Redundancy Configuration and loading Characteristics, Distribution Architecture, Use of EC Motors for PACs, Lighting controls, Operations at Threshold levels close to capacity by means of deploying effective continuous monitoring, alerting and responding mechanisms.

Key Benefits

PUE/DCE metering benefits

- Opportunities to improve a data center's operational efficiency saving significant $$$ in DC Operational expenses.
- Where energy availability is limited, explore opportunities to repurpose energy for additional IT equipment
- Provides an additional critical input for taking long term business decisions like DC Consolidations and DC retrofits.
- How a data center compares with industry- bench marking

DC Density Enhancement and utilization of current technology servers

Performance gain thru deployment of High density Dual Core/Quad core Servers against Low density Single core servers.

Overall reduction in TCO by enhancement in Power/Cooling efficiency and ability to provision High performance current technology server loads.

Case Study – Measuring Efficiency in DC "A" @110W/Sq ft. Vs DC "B" @250W/Sq ft.

DC "B" was provided with separate energy meters for IT Loads and Cooling Load (DX Units) at the time of construction itself

DC "A" – DC using chilled water based PAC units

- Chilled Water Plant common between DC, Labs and office space.
- Hence Flow meters and temperature sensors were installed along with regular energy meters for measuring the IT Loads and cooling loads.
- All the meters have been hooked up to the BMS system for more effective continuous availability of measurements.

The measurements have been collected and analyzed for efficiency requirements.

Analysis - PUE details and comparison for DC "A" and DC "B" Datacenters.

DC "A" - Previous Generation DC with around 40% utilization of cool Air(60% bypass design).

PUE Index value – 1.97 ; DC Efficiency – 1/PUE – 50%

Extrapolated Power cost for the DC – ~880K USD Per Annum

DC "B" – Current Generation DC with around 80% utilization of cool Air(20% bypass) with Chimney Racks & PAC Units Ducted to false ceiling.

PUE Index Value – 1.67 ; DC Efficiency – 1/PUE – 60%

Extrapolated Power cost for the DC – ~660K USD Per Annum

Annual Cost Savings expected in improving the PUE index of DC "A" to the levels of DC "B"- ~150K USD

For additional details refer Slide No 31 in Back up

Action Plan - Upgradation of Power Density & efficiency of DC "A"

Power -

Move of Power Infrastructure from N+N to N+1 considering the DC hardening efforts and resultant environment stability in the DC and also the segregation of Batch Infrastructure and Core Infrastructure with differential Power reliability requirements.

The move from N+N to N+1 increases the power capacity to 1MW in this DC.

Cooling -

It has been established using Tile Flow analysis and Air Flow calculator measurements that the existing cooling is sufficient to handle this increase in Power with a minimal retrofit to the DC layout with population of primarily 1U Servers.

- Continued…..

Continued ……..

Planned Retrofits to achieve the increase in Power density and management of the same :

To meeting increased cooling needs- challenge is to move from 60% bypass to 20% bypass.

- Ducting of the existing PAC units to the False Ceiling.
- Meeting additional capacity requirements at the Chiller Plant.
- Replacement of existing conventional Server racks with Chimney racks or use Hot Aisle Containment units.
- Replacement of the existing grid tiles with greater than 44% Grates

To meeting increased Power needs- challenge is to distribute 1MW of Power where currently 600Kw of power is distributed.

- Paralleling of the UPS infrastructure to move from N+N to N+1
- Up gradation of the main distribution panels to higher sizing to meet the increased power density requirements at the DC level.
- Up gradation of ROW wise breakers to higher sizing to meet increased power density requirements at the ROW/Rack level.
- Up gradation of Power cable sizing to carry higher current requirements.
- Up gradation of Main LT panel to meet the extra power demand.

Upgradation of Power Density & efficiency of DC "A" – Return on Investment*

High level Cost information :

High level cost of retrofit of DC "A" to accommodate 1 MW of power with existing cooling ~ 750,000.00 USD

High Level saving in annual operational power cost due to the improvement in efficiency on account of increased power density in the Datacenter – ~150,000.00 USD

Benefits :

It shows approximately 5 yrs of running of the DC provides the return in Investment for the retrofit in terms of cost saved vide efficiency.

Also approximate addition in power to the DC – 400Kw

High Level construction $$$ per Kw for the additional power to the DC – 1.875K$/Kw. (Current Industry Standard are 10K to 20K US$/KW)

Also the addition of 400Kw power to the DC means provision for additional landing of ~900 1U Quad Core Servers in the DC. (With the current application characterization specific to the project catered by the DC each Quad core server is approximately equivalent to between 5 and 6 Singe core Servers in terms of performance)

* - The figures provided are based on high level project feasibility study conducted internally for the specific DC considered and will vary between different DCs.

DC "A" - DATA CENTER AIRFLOW CALCULATOR with Chimney racks @12Kw

106	Number of Cabinets in Module	16	Work Cell Size (sq ft)	114	# of Diffusers/
5,500	Module Area Including AHU rooms (sq ft)	100%	Overall DC Module Server Utilization	24	RMF Height (

Server Type: 0 = 1U 1 = Blade	QUANTITY OF EACH TYPE (kW) CABINET	CABINET RATING (kW)	% OF CABINETS	Cabinet Work Cell W/sf	CFM /Cabinet	TOTAL CABINET WATTS	Air Velocity Above Floor Tiles (fpm)	Module Statistics	
0	85	12.0	80%	750	1,457	1,020,000	364	127,503	Total Design Airflow to Servers w/o redund bypass (scfm)
0	6	1.4	6%	84	164	8,100	41	153,003	Total Design Airflow to Cold Aisle (scf cabinet bypass, no redundan
0	4	1.7	4%	106	206	6,800	52	166,913	Total Design RAH scfm w/ redundancy bypass losses
0	2	3.0	2%	188	364	6,000	91	**13,909**	**Design ACFM per CRU/RAH w/ rec cabinet bypass losses incl**
0	4	2.0	4%	125	243	8,000	61	**1,342**	Average scfm per floor diffuser or flow thru cabinet plus bypass and floor le
1	5	0.5	5%	31	32	2,500	8	326	Cabinets and CRU/RAH motor heat in To building skin or people heat
			100%	**Total load of all cabinets->**		**1,051,400**	**Watts**	**620**	**W/sf @ 16 Sq Ft Work Cell**
		9.919	AVG	Total Fan BHP	107.9	**1,168,222**	**VA**	**191**	W/sf based on Total Area
	12	**# of CRU/RAH's**		Motor Heat (Watts)	94,686	Facility Equipment Multiplier	1.684	9,223	Average watts cooling per diffuser c
	22	A/C Server System Delta-T (deg F)		**Operating ACFM per CRU/RAH**	**12,750**	Minimum Coil Design Delta-T (deg F)	**23.88**	1,696	TOTAL AMOUNT OF WORK CELL ARE COLD, AND HOT AISLES
	20%	Airflow Bypass		Lighting Heat (Watts)	11,000	DC ChW tons	330	19.3	Layout Efficiency (cabinets pe
				Watts fan power per watt of IT equipment	0.0901			51.9	**OR** Layout Efficiency (Sq Ft per C

INSTRUCTIONS:

STEP	INPUTS IN BLUE CELLS, OUTPUTS IN YELLOW CELLS	Cells
1	Enter the Total Area of Data Center (incl AHU space)	C3
2	Enter Server Type (0 for 1U, 1 for Blade)	B5 - B10
3	Enter Quantity of each type of Cabinet	C5 - C10
4	Enter kW for each type of Cabinet	D5 - D10
5	Enter Quantity of RAH or CRU type Air Handlers	C13
6	Enter Percentage of Air that will bypass the Servers	C15
7	Enter number of Floor Diffusers or Chimney Cabinets	M2
8	Enter Raised Metal Floor Height [repeat steps 5 & 6 to get desired coil delta-T (Cell I-14) & CRU/RAH size (Cell J-8)]	M3

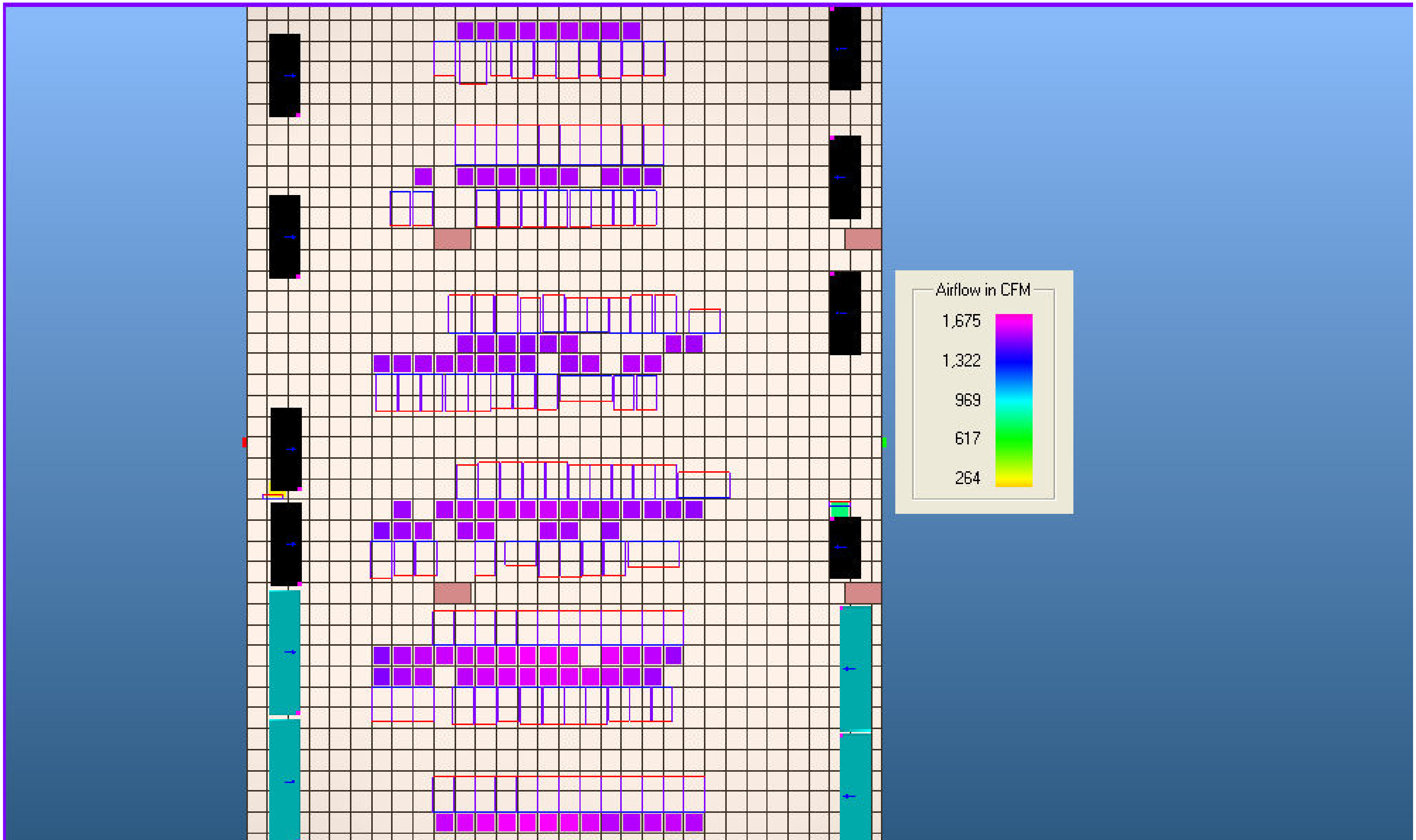
FACILITY INPUTS:

FAN TSP	2.75
FAN EFF	61.36%
Fan Motor EFF	0.85
UPS Efficiency	84.00%
Power Factor	0.90
Altitude Adjust	1.00
Power $/kWh	0.08
ChW Sys. Eff.	0.98
Chiller Eff (kW/ton)	0.590

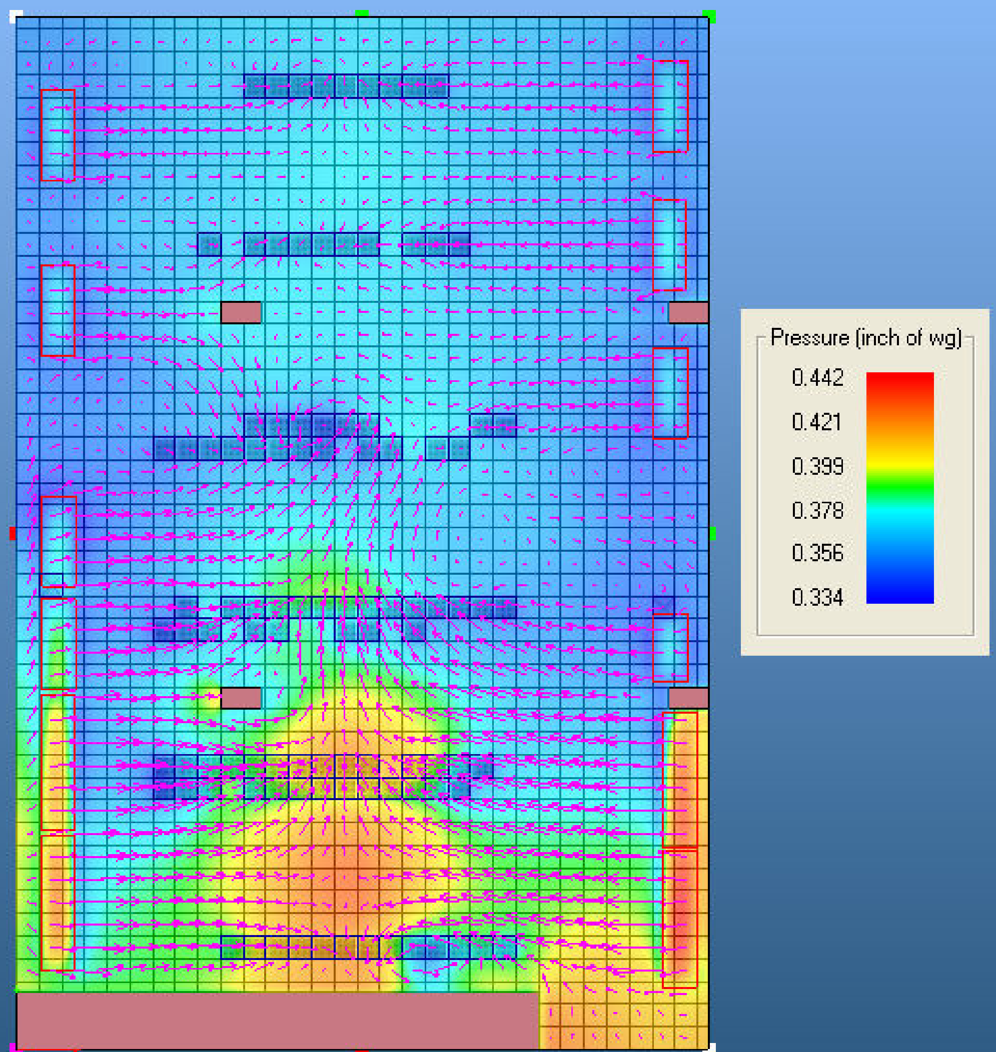
FACILITY OUTPUTS:

UPS HEAT	183,374	WATTS	
	625,854	BTU/Hr	
	57	TONS	
ACAE	6.87	W/cfm	
Facility + IT Power	**1,771**	**kW**	**kVA**
387	Total ChW tonnage		
$159,966	Cost/yr to run chillers		$265,706

DC "A" CFM Flow Modeling Output with existing infrastructure



DC "A" Static Pressure with existing infrastructure.



Critical Observations from the CFD analysis of DC "A" with current cooling infrastructure.

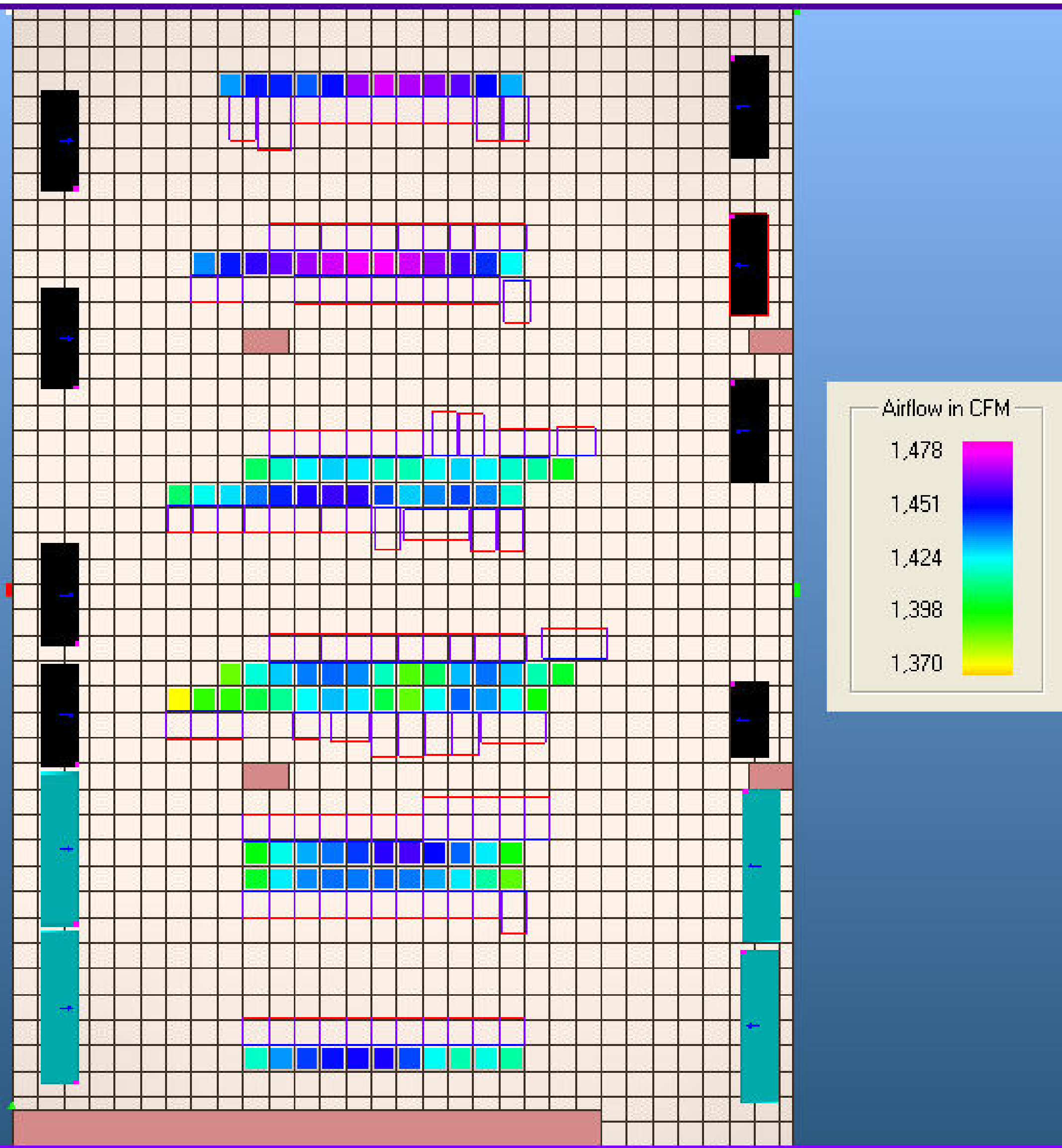
•The DC air flow CFM varies between 264 to 1676 per Perforated Tile currently.
•The temperature is more or less uniform around 55 Deg F to 60Deg F throughout the DC.
•This is a very inefficient utilization of Cooling inside the DC.
•The total approximate cooling available is more than 1MW for a current Maximum IT Load capacity of 600Kw.

•With a more efficient Air Distribution model using Chimney racks / Hot Aisle Containment solution and necessary infrastructure in utilities, the overall power density of the DC could be increased to about 1MW.

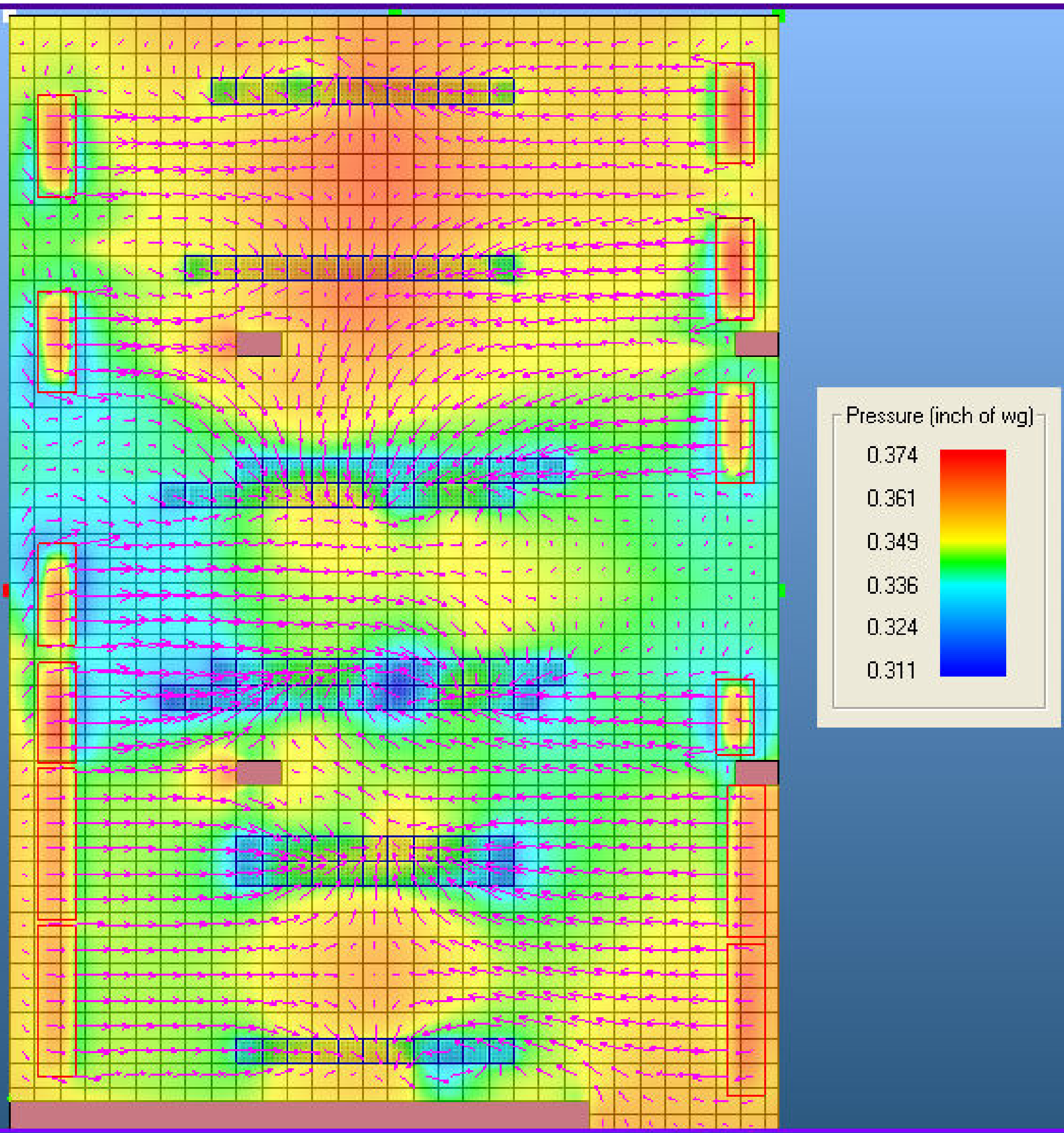
•This also increases the overall power/cooling efficiency of the DC saving huge $$$ in operational costs.

•This DC has adequate Hard floor to Hard roof height.
•False ceiling is also available.
•False floor with depth of 24 Inches is available.

DC "A" CFM Flow Modeling Output with Chimney racks@ 12Kw each & PACs Ducted to false ceiling.



DC "A" under floor Static Pressure



Critical Observations from the CFD. Analysis of DC "A" with upgraded infrastructure @1MW

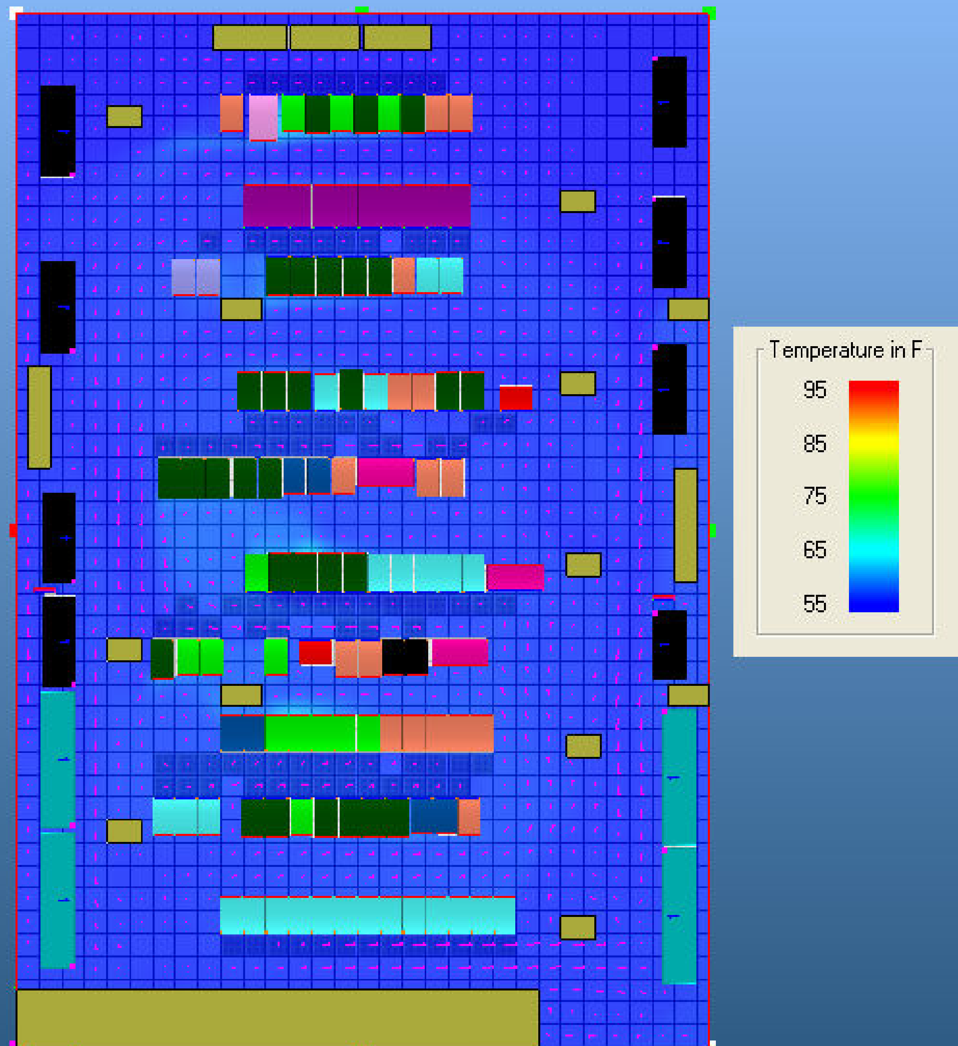
- The Airflow CFM in the DC is now more uniformly distributed and varies between 1370 to 1478 CFM per Perforated tile.
- The temperature is more or less uniform around 55 Deg F in the cold aisles and about 87 Deg F inside the Chimney Ducts and the False ceiling.
- This means an effective Delta of 22Deg F (Better PAC efficiencies)
- This is a very efficient utilization of Cooling inside the DC.
- With a more efficient Air Distribution model using Chimney racks / Hot Aisle Containment solution and necessary infrastructure in utilities, the overall power density of the DC has been increased to about 1MW.
- This also increases the overall power/cooling efficiency of the DC saving huge $$$ in operational costs. (savings of ~150K USD Per Annum)
- The storage and ATL Racks are left without any change and it does not have any impact in the overall cooling performance of the DC.

Key Take Aways

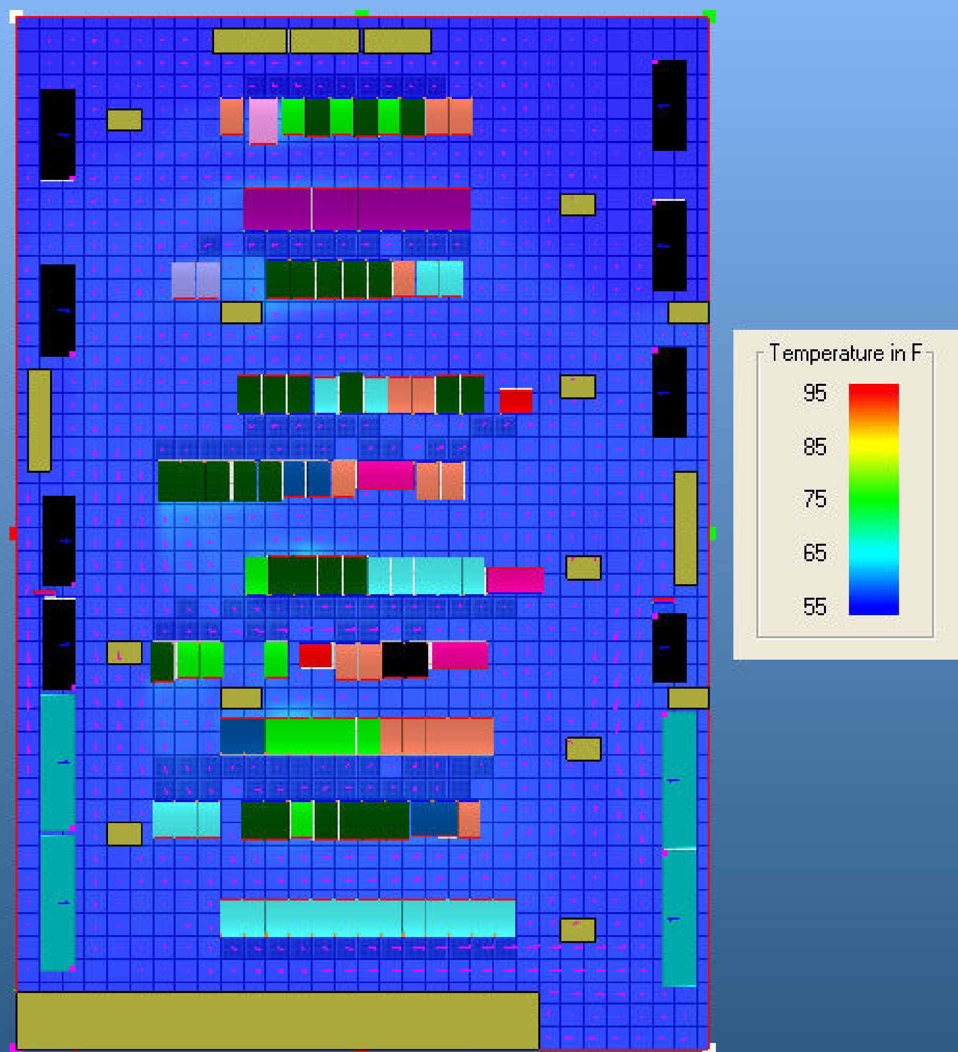
- Improving the power density of this older generation DC using Chimney Racks/ Hot Aisle Containments and Ducting of PAC Units and effective usage of false ceiling also effectively improves the efficiency of this DC.
- This results in value $$$ saved in the operational power cost of this DC (~150K USD per annum)
- The cost of acquiring 400Kw of additional power @ ~1875$ per Kilo Watt against a normal New DC Construction cost of 10K to 20K USD per Kilo Watt - A very cost effective means of adding capacity.
- The net $$$ saved provides the ROI for the retrofits required for the improvement in power density of the DC.
- It would be a very useful to measure the efficiency values of all the DCs and also ensure the efficiency value is also one of the prime criteria of classification of the DCs like Watts/Sqft, Reliability Number etc.
- A higher density environment capable of hosting High Performance Multi core servers that deliver lower operating costs and improved overall performance in multi tasking environments without significantly increasing energy consumption

Back Ups

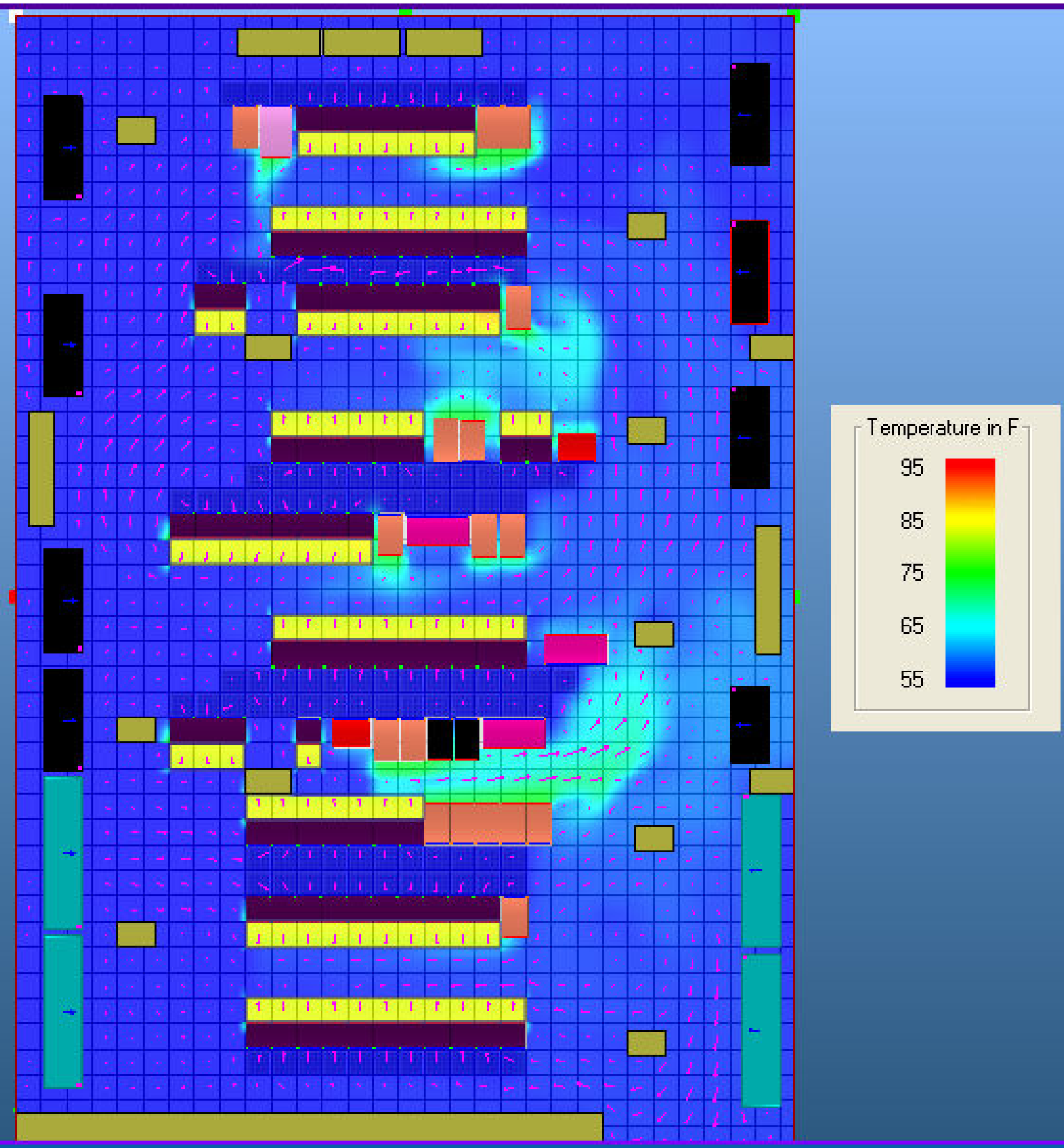
Three Foot Elevation Cooling Performance with existing DC "A" infrastructure at 600Kw IT load



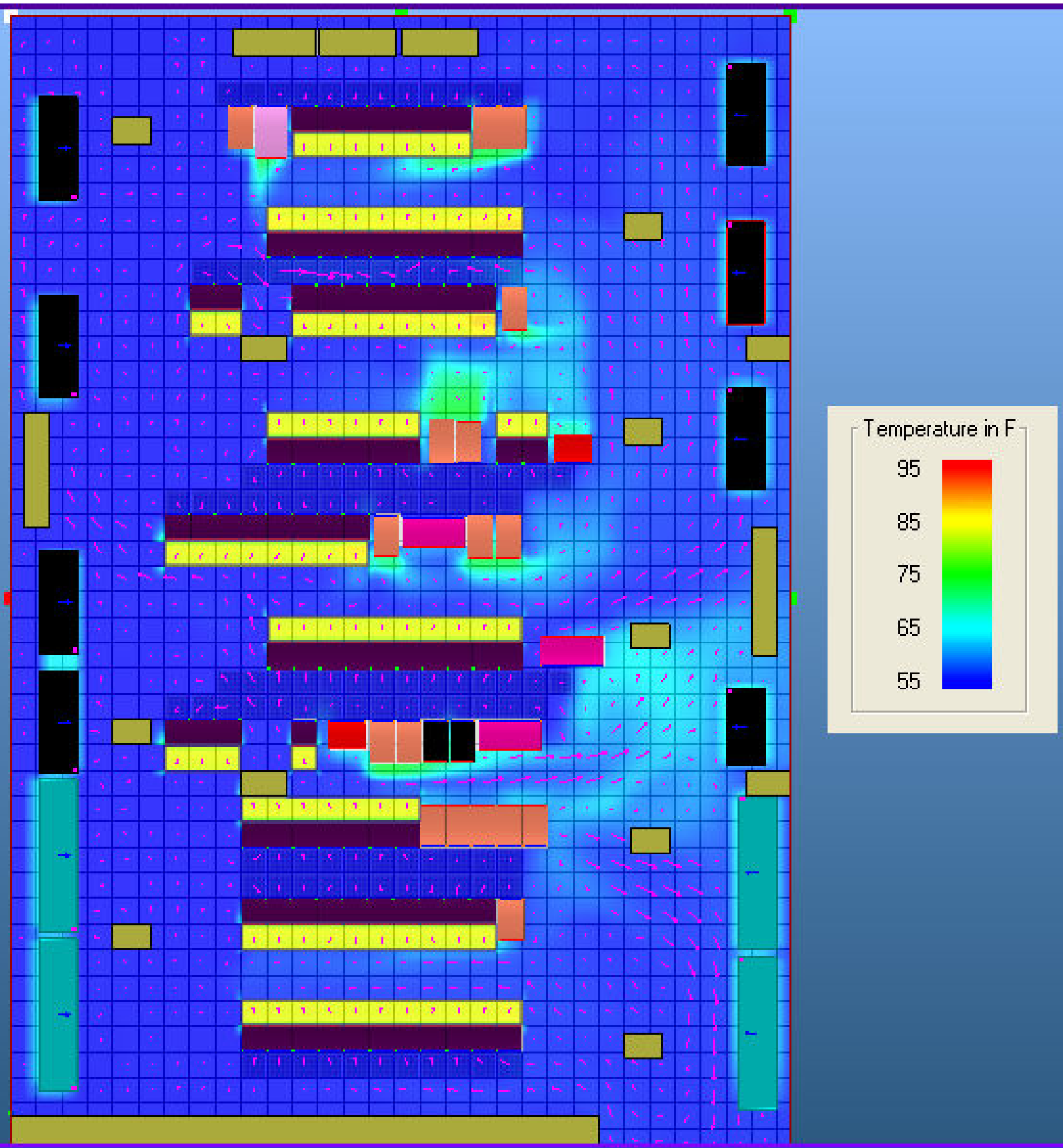
Six Foot Elevation Cooling with existing DC “A” Infrastructure



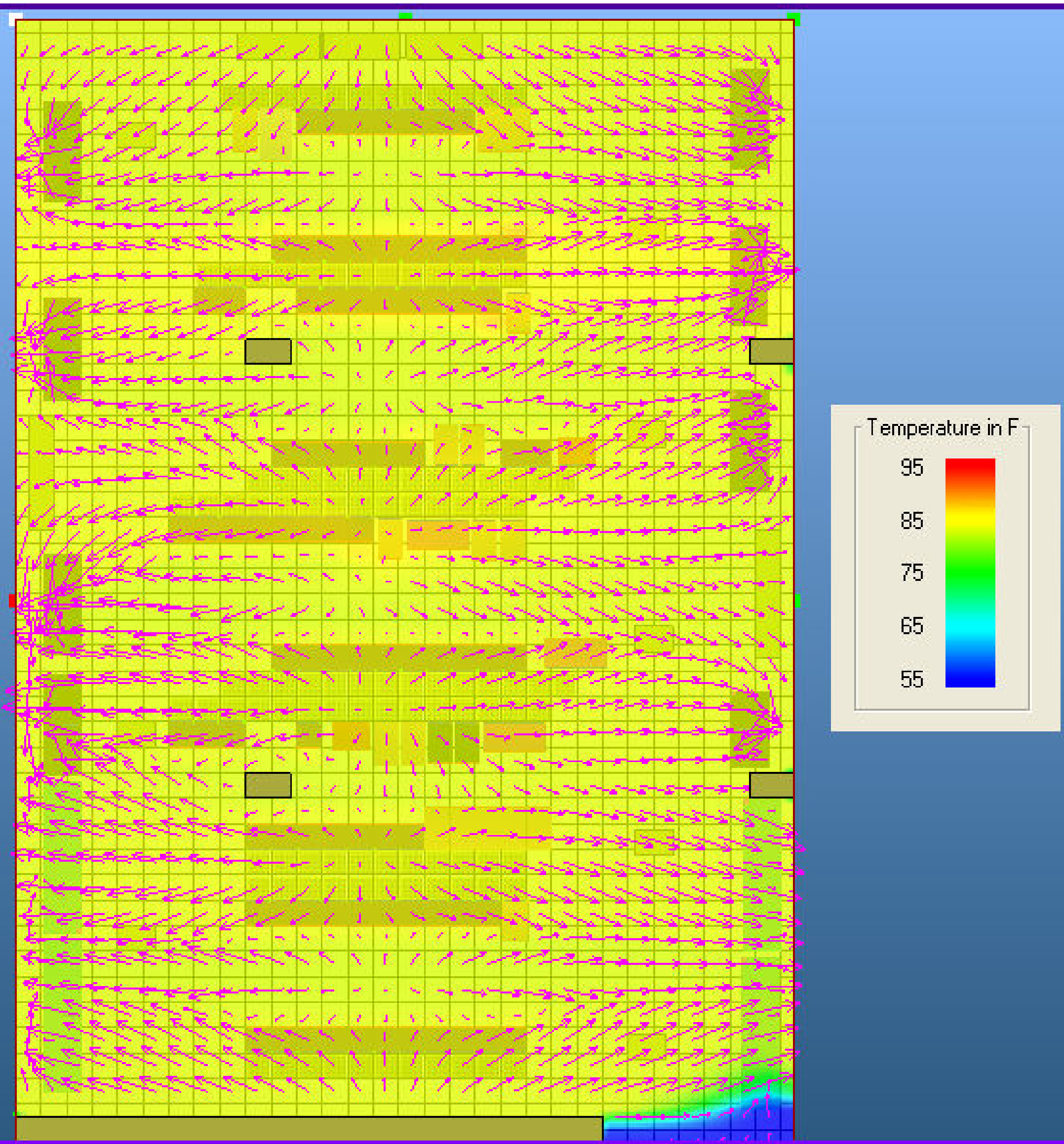
Three Foot Elevation Cooling Performance with upgraded DC "A" Infrastructure & 1 MW IT Load



Six Foot Elevation Cooling Performance with upgraded DC "A" Infrastructure & 1 MW IT Load



Above Ceiling Airflow pattern with upgraded DC "A" Infrastructure & 1 MW IT Load



PUE value and impact in Operational costs with Normalised loads

The data is the first set of data after the installtion of the metering facility.
Hence this is a high level information. However no huge variations are expected.

DC "A"	Value in KWH	DC "B"	Value in KWH
Average IT Load per Day	10,164.00	Average IT Load per Day in the DC	10,164.00
Average UPS & Distribution losses per day @14%	1,422.96	Average UPS & Distribution losses per day @8%	813.12
Average cooling load per day	8,520.00	Average cooling load per day	5,926.76
Average Lighting Load per day in the DC	160.00	Average Lighting Load per day in the DC	70.00
Total Facility load per day in DC "A"	20,266.96	Total Facility load per day in DC "B"	16,973.88
Total IT Load per day in DC "A"	10,164.00	Total IT Load per day in DC "B"	9,012.00
PUE (Power Usage Effectiveness) in DC "A"	1.99	PUE (Power Usage Effectiveness) in DC "B"	1.67
DCE (Datacenter Effeciency) in "A"	50.15%	DCE (Datacenter Effeciency) in DC "B"	59.88%

Annual Total power cost for DC "A" in USD	887,692.85	**Annual Total power cost for DC "B" in USD**	743,455.94

Differrence in Annual power cost between DC "A" and DC "B" in USD	144,236.90

The figure of approx 150K USD is the amount annualy we can save if we improve the efficiency by around 10% in DC "A" and bring it to the level of DC "B".